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# Animal Telemetry Network Data Assembly Center: Phase 1

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## LONG-TERM GOALS

The capacity to track aquatic animals with biologging techniques enables a new scientific capacity for studying of animal migrations in the marine environment. In the past two decades, rapid advances in the small transmitters, receivers, and data storage tags that are attached to animals have made it possible to collect high-quality biological and oceanographic observations on timescales varying from days to years as the animals move through aquatic habitats. Biologging science, provides information that is used to support the management of marine fisheries and endangered and protected species, to assess the potential effects of anthropogenic disturbances, and to improve ocean modeling and forecasting. The U.S. is a global leader in animal telemetry, with tremendous telemetry infrastructure and considerable technical expertise in telemetry operations. However to date, centralization of the biologging data stream has not occurred.

This data assembly center project for the ATN is part of a broader on-going collaboration between IOOS and the animal telemetry community. IOOS and ATN participants are currently updating a 5-year strategic plan that describes this collaboration, including the phased development of a sustainable ATN Data Assembly Center (or DAC) for data collected by the growing U.S. community of marine animal taggers or biologgers. The ATN is supported by multiple federal agencies that have are considering how together they can be responsible for the coordination of ATN activities and operations throughout IOOS regions.

The revised strategic plan presents a broad vision for an animal telemetry network as a core component of IOOS that will:

- Facilitate the organization of local animal telemetry systems into confederated regional nodes;
- Facilitate integration of animal telemetry instruments with existing observing systems;
- Improve data standards, management, sharing capability and establish a cyber- infrastructure for archiving and displaying telemetry data;
- Serve as a focal point for the development of new sensor technology;
- Bring permanence and sustainability to a national telemetry network; and
- Expand animal telemetry outreach and education programs.

## OBJECTIVES

As set forth at the onset of the project, the project goals of this project were:

- To establish an ATN data assembly center with a data portal and visualization tools to enable public access to data/metadata from marine animal tags;
- Applying existing IOOS DMAC data standards, vocabularies and other established DMAC protocols and services; and
- Ensuring the initial version is also compatible with established international programs that distribute data from tagged marine animals including Australia's Integrated Marine Observing System (IMOS) and Canada's Ocean Telemetry Network (OTN).

The project objectives were specifically:

- To establish in approximately 12 months, a scalable data portal that successfully enables public access to selected data from marine animal tags (Archival, Satellite and Acoustic) and from several marine animals (Fish, Sharks, Marine Mammals, Turtles and Seabirds);
- Deploy this portal on an existing, dedicated, stand-alone computer server at Hopkins Marine Station in Pacific Grove with backup at Stanford University in Palo Alto, CA and the NOAA PMEL facility in Pacific Grove, CA;
- Ensure the provision of priority core functions including data storage, downloading and archiving, delivery of priority user-defined data products, and implementation of quality control improvements

## APPROACH

Based on technical recommendations from two U.S. IOOS Program (IOOS) hosted national Animal Telemetry Network (ATN) workshops, and a recent successful collaboration between IOOS, the U.S. Navy and NOAA's National Weather Service on improved access to ocean observations from tagged marine animals, IOOS, including Regional Associations, and the U.S. Navy (Naval Oceanographic Office and Office of Naval Research) have identified the need for a national and publicly accessible ATN data management capability. This includes the sustained delivery from anywhere in the world of real-time/near real-time marine animal telemetry data to a web-accessible portal with data visualization tools, and timely data delivery to IOOS Data Management and Communications (DMAC) web services and the WMO Global Telecommunication System (GTS). This report describes the initial phase I for establishing this capability.

Co-funded by US IOOS and the US Navy's Office of Naval Research, this Data Assembly Center (DAC) project set out to establish an initial capability for public access to and use of tag and ocean data collected from mobile marine animals. The work was executed at Stanford University's Hopkins Marine Station by scientists and computer programmers from Stanford's Tagging of Pacific Predators (TOPP) program in collaboration with NOAA Fisheries in Southwest Fisheries Science Center Environmental Research Division (SWFSC/ERD). The project builds on substantial existing capabilities of the TOPP program and SWFSC/ERD data management and distribution tools including refinements funded by NOAA to support the Damage Assessment, Remediation and Restoration

Program (DARRPA) phase of the U.S. Government's response to the Deepwater Horizon Oil Spill in the Gulf of Mexico.

The U.S. IOOS Program hosted ATN workshops in 2011 and 2012 with the nation's marine animal tagging community to identify opportunities for collaboration and to advance the concept of a national marine animal telemetry network. Subsequent reports document recommended priorities, highlighting in particular a community need to adopt standards-based protocols for data from tags. Based largely on these recommendations, IOOS has worked closely with data providers and users to describe standards for data format and content, and to promote the use existing tools for data sharing. One example of a pilot project conducted with Stanford University, University of California and co-funded by IOOS and the Office of Naval Research (ONR) provided improved access to physical oceanographic data from elephant seal satellite tags to ocean modelers at the Naval Oceanographic Office (NAVOCEANO) and at the National Centers for Environmental Prediction in NOAA's National Weather Service. Data from 350 historic tags deployed during the TOPP (Tagging of Pacific Pelagics) and two live/active tags were made accessible to NAVOCEANO modelers and 8,138 direct observations were successfully downloaded and assimilated.

**RESULTS**

The ATN DAC currently through Phase I development provides access to four data streams: 1) A "live" from the animal borne platform data stream that reports automatically from Argos satellites via codes that directly download from the CLS to Stanford servers and then display location and data sets to the DAC in near real time. This data stream is customized for tag platforms built by SMRU (Satellite Relay Data Logger, Fastloc GPS), Wildlife Computers (SPOT and SPLASH) 2) Acoustic data (white sharks) via automated Iridium satellite-linked Vemco receivers mounted on stationary buoys or mobile platforms such as Liquid Robotics Wave Gliders; and 3) Pop-up satellite tags (e.g. Wildlife Computers MK10, MiniPAT) that report throughout the year (e.g. blue marlin from the IGFA Great Marlin Race), and then take approximately 20 days to download as the tag floats at the surface and transmits data to the DAC. The DAC servers collect oceanographic, position and behavioral data archived on the tag and rapidly displays it, and 4) the archival based datasets drawn from the several thousand animal tracking deployments and datasets collected through the prior TOPP, GTOPP programs (Census of Marine Life), as well as Atlantic bluefin tuna tagged through the Tag A Giant program with implantable archival tags and pop up archival tags (already deployed and recovered).

Currently, 48 different species are represented in the ATN DAC (with datasets), with deployment dates ranging from 2000-2014 (see Table 1). In addition, the interface provides access to acoustic buoy detection data from 20 receivers located in 13 different sites -in the US and Canada. The beta DAC system also demonstrates the capacity to pull data from remote locations across the globe, with streams coming from US territories (Palmyra-acoustic tagged mantas) and the Chagos Archipelago (reef sharks, silvertips, grey reef sharks). On these live acoustic receiver buoys at the DAC, there are currently 7 species reporting daily which complements the 4-5 species reporting through the satellite ARGOS tags. There is also a placeholder in the data structure for archival glider data. Three glider expeditions are currently planned early in the 2015 and code for reporting of this data stream has already been designed and tested. This placeholder will be used to display the track of the glider and animal acoustic detections.

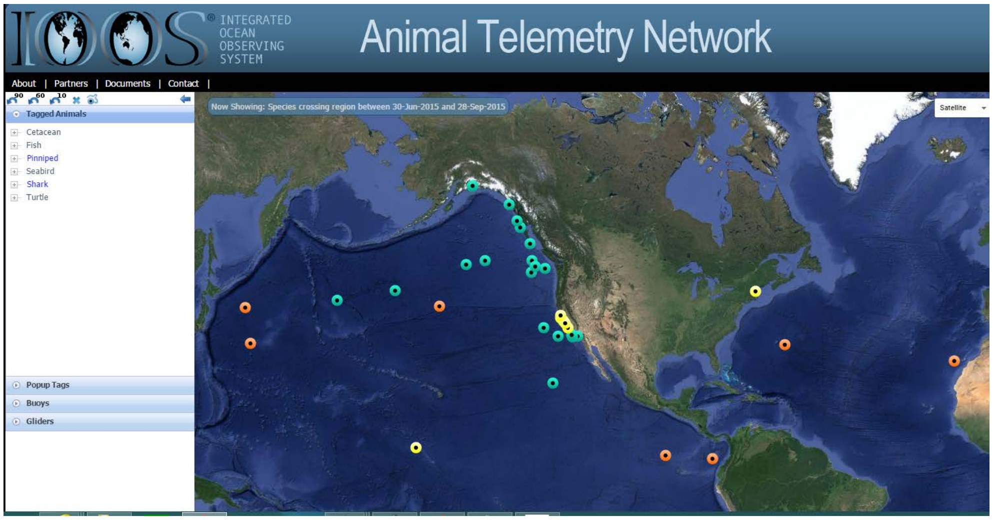


***Figure 1. The Interface for exploring ATN tag data***

The default view of the IOOS DAC interface shows the most recent data (users can select from 10, 60 or 90 day displays), and the interface features a pull-out "Data Menu" which allows them to view or hide datasets from all these species and platforms by clicking check-boxes arranged in a hierarchical, nested structure - similar to that used in Google Earth to activate and deactivate various data layers (Figure 1). For example, a user can view all the blue whale tag datasets by clicking a single box; or they can drill down to individual deployment years (e.g., to display all the tags deployed in 2004), or even down to individual tags (tag number "2204001-2306-MatePTT"). At the individual tag level, users can also view, download or access the data through an ERDDAP server, all directly from the Data Menu (i.e., without having to locate that specific tag on the map first.) The ERDDAP server enables users to quickly query, visualize and download data in several different formats. More importantly, once the user has created a query, ERDDAP provides a restive URL for that query which can be incorporated directly into other systems (e.g., websites, Matlab routines, models) which require ongoing access to those data streams.

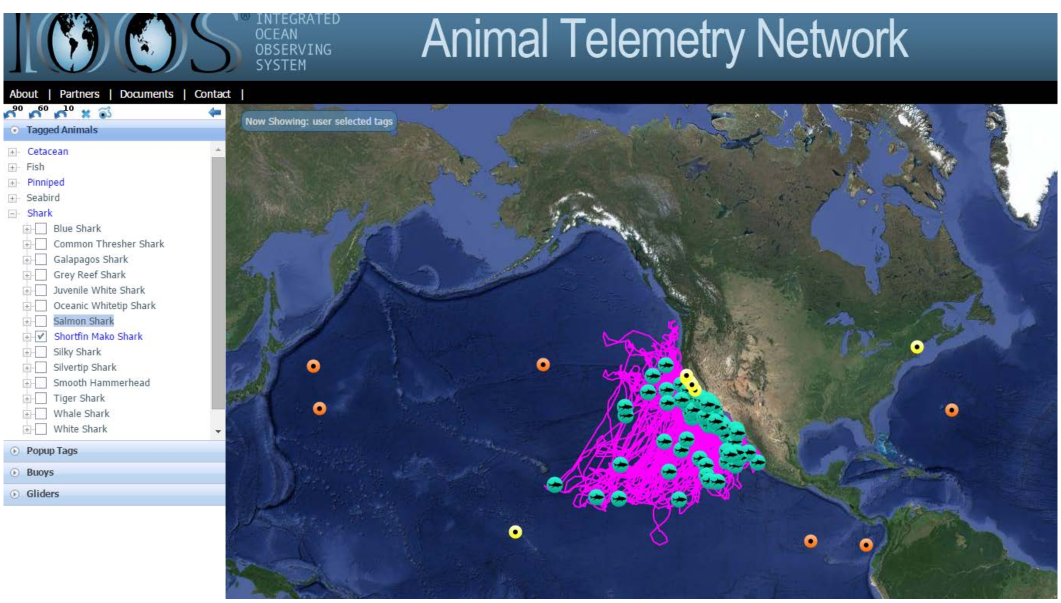


***Figure 2. A display showing exploration of the larger data sets to browse (Mako Sharks)***

The ATN DAC development team under 2014 funds continued to add and refine additional datasets available through the ATN DAC interface, which includes adding species not currently represented, continuing to upload data sets from the TOPP and TAG programs which are in highest demand (whales, tunas), and ingesting additional data associated with 2014 deployments and display tracks already in the interface (e.g., depth and temperature profiles). Other ongoing tasks include: production and integration of profile plots for real-time data from oceanographic tags into website interface; production and integration of buoy detection plots into acoustic buoy displays; and production and integration of buoy metadata into the ATN DAC interface. These tasks were completed by the end of 2014. At the completion of Phase I, the demonstration of being capable of serving live and archived data from numerous tag platforms will have been successfully achieved.

*BROWSER and ATN DATA ACCESSIBILITY*

In the time since the project launch, there have been a number of additions and refinements to the ATN DAC interface, including:

- Addition of the ability to show or hide all currently active tracks in the current view with a single click
- Addition to clear all animals from the current view
- Improved metadata displays for acoustic buoys
- Enhanced data displays for acoustic buoys
- Ability to show mobile glider data where animals had been detected on receivers

There are continual improvements on the presentation of the oceanographic profile displays such that real-time elephant seal and shark data displays provide actual start to current profiles along a track in near real time (Figure 3). Additionally as the DAC phase I was coming to completion we had mapped a plan for improving the handling of miniPAT tag data currently displayed in near real time from pop up events. We anticipate that these tasks will be completed before the end of December 2015.

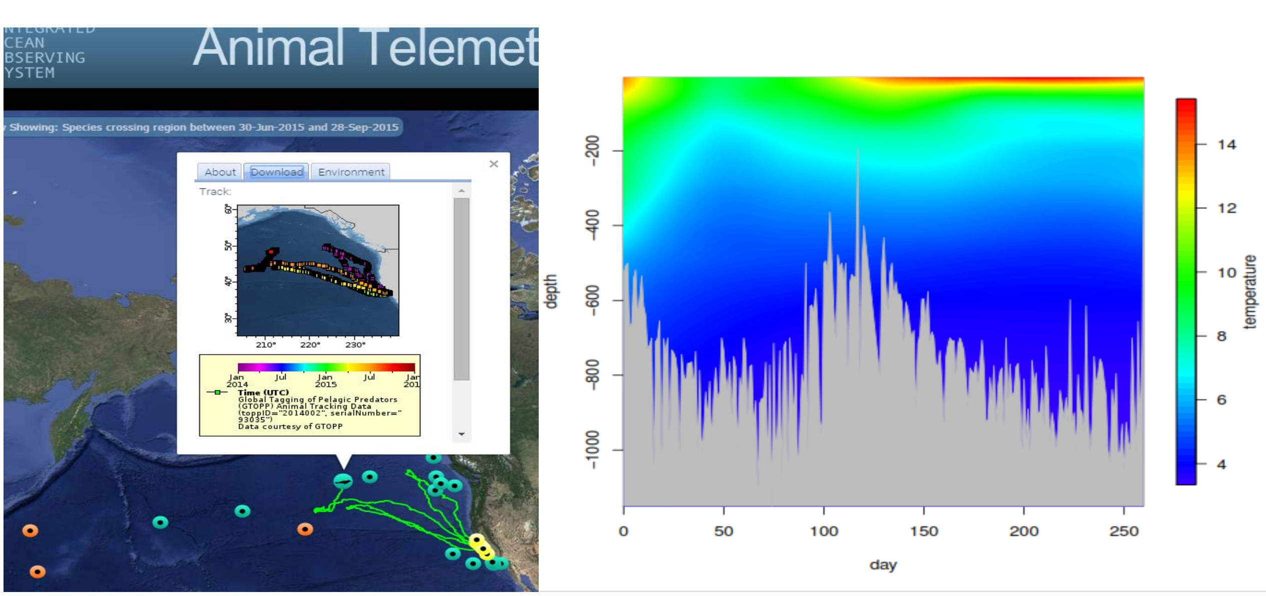


***Figure 3. Real time CTD Data from an elephant seal. Tracks and profile data are available and can be downloaded with the interface***

A novel feature of the ATN is the ability to get live buoy data from automated satellite enabled Vemco buoys (Figure 4). Currently six Iridium enabled buoys are accessible for download from the main browser page. Each displays a live data set (from white sharks, mantas) at the specific location. Refresh is 24 hours and data is compiled for the duration of the particular buoy.

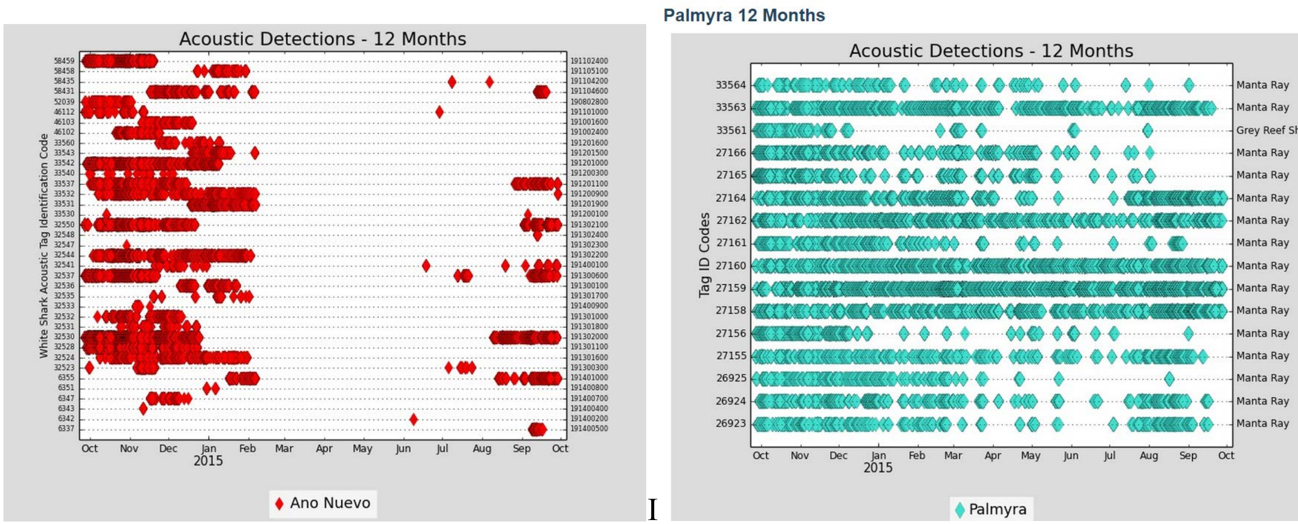


***Figure 4. Buoy displays on the ATN showing live data compiled over a one year period.***

In addition to the interface improvements listed above, we are completing installation of a new primary server for the system for Phase 2, which includes updated hardware and software to improve overall system performance, stability and security.

Future work proposed in Phase 2 of this project, will include additional improvements to system infrastructure, increased metadata in compliance with IOOS standard formats and nomenclatures, and the development of tools to allow integration of datasets from outside the TOPP data domain (e.g., MARES, NOAA). In addition, we explored the capacity to map continuous glider data from a mobile platform (Wave Glider) and discern how best to provide detections in a useable format. This involved receiving live data from the platform via Iridium, coding the data stream for machine to machine automated updates- and then identifying the acoustic tagged animals (white shark, salmon, steelhead). The team finished the coding the live stream was displaying and integration of the glider data stream with the ATN DAC was completed (Figure 5). Some effort has been put in to the visual tabs in the ATN DAC for viewing glider information with various tabs explaining the outputs from the glider. The glider was removed just at the time we finished coding for the ATN DAC and will be fully implemented in Phase 2.

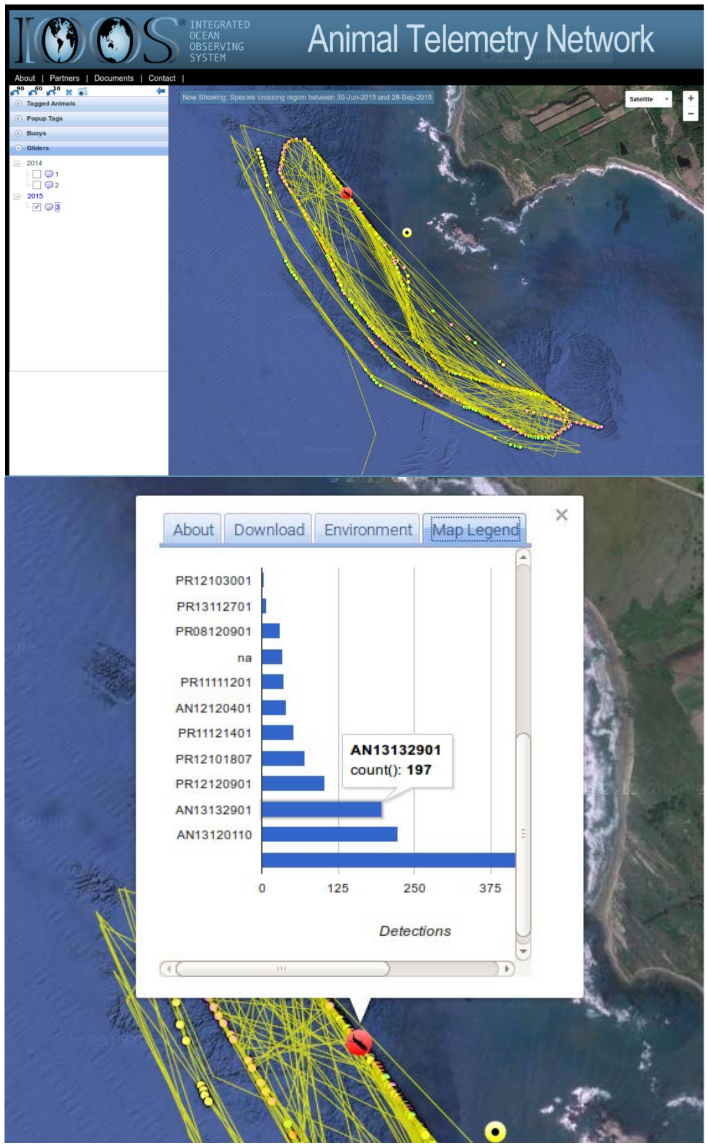


***Figure 5. (Top) a projected view of the glider and detections (circles) at Ano Nuevo. Potential display of acoustic White sharks and frequency of detection shown in pop up window.***

## IMPACT/APPLICATIONS

Phase I of the ATN DAC development was intended primarily as a prototype effort, to demonstrate the capability of a system to serve data from a wide variety of platforms used in animal telemetry. We successfully accomplished this task, and have created a unique new browser capable of serving animal biologging data from US waters. The plan in phase II will be to move forward with a more operational implementation of the system, which will include the ability to integrate external data (i.e., data from users outside of the Block Lab/TOPP program) into the ATN DAC. As we expand and refine this system, our hope and expectation is that the data it contains will gain greater use by the broader community of marine biologgers as well as biological, physical and chemical oceanographers and ocean modelers who can use the data these animals provide. As we continue to expand and refine the ATN DAC system, one goal will be to begin to train users in how to take advantage of the functionality of the system. For example, NAVO is currently using the real-time GTS feed from the elephant seal SMRU tags to pull the data from these animals into their oceanographic models. This could also be accomplished using an ERDDAP server, which can feed real-time (or near-real time) data in a variety of formats, simply through the use of restive URLs that can be incorporated into software systems (e.g., MATLAB code) to query data in the ATN DAC. The power and flexibility of the ERDDAP server is one of the

We expect in Phase II to deliver more realtime on line products, and have summary data that may intuitively be digested by the public who might be viewing the data. One type of very common tag is the pop up satellite archival tag. We anticipate having all tags in a uniform output that provides access to time series data in a raw format, as well as sophisticated plots of the data for summarized download. An example of a map, depth and temperature data in a simple and automatic download form is shone in early application below in Figure 6.

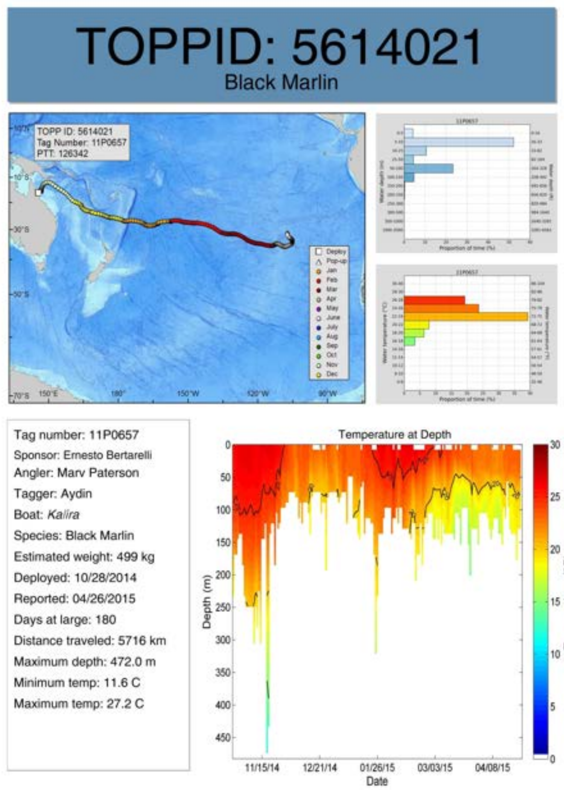


***Figure 6. Compilation of display and analyses from a mini-pat tag on a bluefin marlin. This data feed will be automated in Phase II and provided once a pop up satellite archival tag downloads its data set***

**RELATED PROJECTS**

The ATN DAC project builds on a decade of work done in the Tagging of Pacific Predators (TOPP) program, for which the TOPP data management system was first developed. The software for this system was further refined and improved for the GulfTOPP system, used in the NOAA National Resources Damage Assessment process following the *Deepwater Horizon* oil spill, and many features in the ATN DAC were first developed as part of the GulfTOPP effort. We are also using many of the data processing and management tools in collaboration with the International Game Fish Association for our IGFA Great Marlin Race project; the data from which are being incoroporated in their entirety into the ATN DAC. We are also using animal telemetry data in a variety of public education and outreach projects, including NSF-funded Ocean Tracks and Ocean Tracks: College Edition programs, the Concord Consortium's NSF-funded Common Online Data Analysis Platform (CODAP) project, and the Exploratorium's NSF-funded Living Liquid exhibit development program. In all of these cases, discussions are happening about how to either leverage or tie in to the ATN DAC to facilitate greater and more efficient data delivery to educators, students and the general public that uses these resources.

Future phases of this work, currently being proposed, will add more data to the portal and enhanced capabilities for data access, distribution, archiving, analysis and visualization based in part on requirements defined in the first steps of this project and on user feed-back when the initial product is deployed.

**REFERENCES**

No Citations

## Appendix 1

***Table 1: Tagged animal datasets currently in ATN DAC and TOPP database***

| Animal | PI | Years | ATN DAC | TOPP DB |
|---|---|---|---|---|
| **Cetaceans** | Bruce Mate | | | |
| blue whale | | 2004-2008 | 32 | 32 |
| fin whale | | 2004, 2006 | 1 | 1 |
| humpback whale | | 2003-2005 | 13 | 13 |
| sperm whale | | 2008 | 4 | 4 |
| | | | | |
| **Fishes** | Block | | | |
| Atlantic bluefin tuna | | 2007-2008 | 6 | 1270 |
| black marlin | | 2011-2014 | 30 | 30 |
| blue marlin | | 2002-2014 | 91 | 91 |
| Pacific bluefin tuna | | 2002, 2005 | 9 | 849 |
| Pacific sailfish | | 2005-2014 | 21 | 21 |
| striped marlin | | 2003-2014 | 49 | 49 |
| swordfish | | 2004-2009 | 12 | 12 |
| white marlin | | 2013 | 6 | 6 |
| yellowfin tuna | | 2003, 2013 | 11 | 609 |
| | | | | |
| **Pinnipeds** | Costa | | | |
| California Sea Lion | | 2003-2008 | 136 | 136 |
| Cape Fur Seal | | 2008 | 6 | 6 |
| crabeater seal | | 2007 | 11 | 11 |
| Galapagos sea lion | | 2005-2006 | 18 | 18 |
| Northern elephant seal | | 2002-2014 | 331 | 331 |
| Southern elephant seal | | 2007-2009 | 32 | 32 |
| Weddell seal | | 2010 | 22 | 22 |
| | | | | |
| **Seabirds** | Shaffer | | | |
| black-footed albatross | | 2002-2009 | 103 | 103 |
| Laysan albatross | | 2002-2009 | 137 | 137 |
| sooty shearwater | | 2005 | 10 | 10 |
| | | | | |
| **Sharks** | | | | |
| basking shark | Wilson | 2009-2011 | 3 | 3 |
| blue shark | Dewar | 2002-2014 | 90 | 90 |
| common thresher shark | Dewar | 2003-2008 | 23 | 23 |
| Galapagos shark | Block | 2006 | 17 | 17 |
| Greenland shark | | 2004 | 1 | 1 |
| grey reef shark | Block | 2013 | 7 | 7 |
| Juvenile white shark | Jorgensen | 2004-2011 | 32 | 32 |
| manta ray | Block | 2004-2014 | 15 | 15 |
| oceanic whitetip shark | Block | 2004, 2006 | 6 | 6 |
| porbeagle shark | | 2008-2009 | 3 | 3 |

| | | | | |
|---|---|---|---|---|
| salmon shark | Block | 2002-2012 | 133 | 133 |
| silky shark | Block | 2004-2013 | 8 | 8 |
| silvertip shark | Block | 2013-2014 | 8 | 8 |
| tiger shark | | 2010 | 1 | 1 |
| whale shark | | 2010-2011 | 5 | 5 |
| white shark | Block | 2002-2013 | 74 | 74 |
| | | | | |
| **Humboldt squid** | Gilly | 2004-2009 | 32 | 32 |
| | | | | |
| **Sea Turtles** | | | | |
| Hawskbill turtle | | 2010 | 1 | 1 |
| leatherback sea turtle | Block | 2004-2007 | 101 | 101 |
| Loggerhead sea turtle | | 2005-2007 | 16 | 16 |